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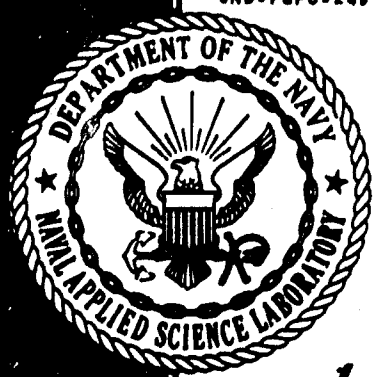

TECHNICAL REPORT

U. S. NAVAL APPLIED SCIENCE LABORATORY

NAVAL BASE
BROOKLYN 1, NEW YORK

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DASA 1721

THE MEDICAL BURDEN FROM SKIN BURNS AT NAGASAKI: A REAPPRAISAL

Lab. Project 9400-12, Progress Report 11

DASA Subtask 03.062

12 October 1965

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ABSTRACT

The medical burden at Nagasaki, i.e., the number of persons who required medical care as a result of receiving skin burns caused by thermal radiation, was determined as a function of the distance from ground zero and radiant exposure. The casualties were computed on the basis of available burn casualty and survival data and a re-estimate of burst conditions. Of an initial population of approximately 174,400, 136,450 were alive after 20 days, of these 8355 persons, or 4.9% of the total population had received serious burns. Of the 20-day survivors, 1800 had been closer than 1000 meters to ground zero, 13.5% of whom had skin burns. A total of 5800 20-day survivors had been at distances of from 1500 to 2000 meters, 18.1% of whom had skin burns. Of the 54,600 survivors who had been at distances of from 4000 to 5000 meters, only 2.9% had skin burns.

The data are presented in a form to allow estimates of casualties for situations resembling those at Nagasaki.

From an analysis of the casualty data and from estimates made by Japanese doctors of the number of persons who survived immediately after the detonation, a casualty rate curve has been derived for the 20-day interval following the detonation.

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ADMINISTRATIVE INFORMATION

The work reported herein was conducted as part of the Naval Applied Science Laboratory's studies for Fiscal Years 1964 and 1965 on the mechanism of thermal injury sponsored by the Defense Atomic Support Agency under DASA subtask NWER 03.062.

ACKNOWLEDGMENTS

The work reported herein was conducted under the direction of W.L. Derksen, Senior Task Leader, and T.I. Monahan, Head, Physics Branch. Dr. George Mixter, Jr., M.D., is a consultant to this Laboratory on the medical aspects of thermal injury.

OBJECT

The object of this analysis was to determine, on the basis of available Nagasaki survivor and burn casualty data the medical burden, or the number of survivors who required medical attention, because of burns as a function of distance and radiant exposure. The data were developed to be used as a basis for estimating the medical burden due to nuclear explosions.

INTRODUCTION

The number of burn casualties properly requiring intensive medical care at Nagasaki, when analyzed and correlated with Laboratory data and recent re-estimates of yield and burst conditions, can serve as a basis for predicting burn casualties under conditions similar to those at Nagasaki.

Much of the information on burn casualties at Nagasaki given in Effects of Nuclear Weapons (ENW)[1] and in Oughterson et al[2] is not directly extensible to the calculation of the medical burden at various times after the detonation. The tabulated data require certain recalculations and reclassification of the data to make them applicable in establishing the "thermal burden." This "burden" is the actual number of living persons requiring intensive medical attention at a given time post-detonation; as deaths and recoveries occur, the load becomes lighter. Estimation of these numbers is of great logistic importance, particularly when they are carefully correlated with the radiant thermal exposures at various distances from ground zero. On the basis of Laboratory data, observations at weapons tests, and theoretical calculations, the radiant exposures can be estimated at a given distance for a given weapon yield.

RADIANT EXPOSURES

The most recent estimates[3] of the weapon yields and atmospheric visibilities for the two Japanese detonations are: for Hiroshima, 16 (±3) kt, 10 mile visibility; for Nagasaki, 20 (±2) kt , 50 mile visibility. Assuming the height of burst in each instance to have been 1800 ft., the distances from ground zero are converted to slant range and, using the ENW slide rule, the thermal exposures for 20 and 16 kt are tabulated as in Table 1. Attenuation for 10-mile visibility is calculated from the chart in ENW and applied to the 16 kt yield. These data are plotted in Figure 1. The exposure data for Hiroshima, although not used in this report, are given in view of their relationship to the Nagasaki values.

CASUALTY ESTIMATES

The information on thermal casualties from Oughterson and Warren[4] can be arranged as a function of thermal radiant exposure. The information given in Table 9N of reference 2 for Nagasaki survivors is listed in Table 2 herein in terms of the radiant exposure level, the percentage of survivors who had burns, and the percentage of these who had second-degree burns as the most severe. The data given in Table 10N of reference 2 are also included, indicating for the cases studied the percentage who had various body areas burned. The two sets of data of Table 2 are combined (by multiplying the appropriate columns, 5 through 10, by column 4) to give an estimated percentage of total survivors who had second degree burns as most severe over various percentages of body surface. The same procedure is carried out for third degree burns to give the data presented in Tables 4 and 5.

The areas of the various geographic "rings" (defined by the range in radiant exposure) were computed and are entered in Table 6, to which are added estimated population densities (ENW, p 550)[1]; the last column of Table 6(the product of the two preceding) represents an estimate of the actual number of persons in the ring at the moment of detonation.

Table 7 gives 20-day casualty data from ENW, with estimated distribution between rings 2, 3, 4 and rings 5, 6, 7. By subtracting these numbers from the last column on Table 6, the number of survivors in each ring at D+20 days are obtained The number of survivors having second and third degree burns of less than 10 percent of body surface is given in Table 8; the data are drawn from Tables 3 and 5; the number of survivors with second and third degree burns of over 10 percent of the body surface is also given. These data are also presented in Figures 2 and 3.

These data are now applied to the survivor figures, giving the last two columns of Table 7, which then is the presumed patient load due to burns in each ring, as of the 20th . / following the detonation.

Table 7 shows that, some 3 weeks after the event, there were probably some 8355 persons with significant burns, comprising some 6.3 percent of the survivors. Of these, 3325/8355, or less than 50 percent, had burns of over 10 percent of the body surface or more. It is to be noted that the entire surface of one arm is about 9 percent of the total body surface; the anterior surface of all of one lower extremity is also about 9 percent. A second degree burn of such extent warrants hospitalization if facilities are available.

The statistical data of reference 2 were analyzed in order to derive a minimum and maximum value of the thermal burden rate during the first 20 days. These extremes, when plotted in figure 4, bracket the thermal burden rate value previously derived and thereby lend more credibility to the more apt figure. The lower value, based solely on the seriously burned statistical cases of reference 2, and the higher value derived by prorating the many unknown survivors who had not been examined, are useful since they serve to delineate the theoretical limits for the thermal burden rate.

The three curves drawn in figure 5 represent the percentages of the population in each ring, at 20 days past-detonation, who either had died or still survived and those survivors who had sustained serious burns, all as a function of the radiant exposure at the respective distance from the point of detonation.

DISCUSSION

The calculations presented above necessarily assume lack of bias in the selection of survivors for study; that this is not strictly true was acknowledged by Oughterson and his associates. It is not possible to weigh the figures to allow for selection; analysis must be made with the data as given, which contributes to the uncertainty of the estimates. Considering this and a number of other assumptions which may well be incorrect, it is believed that the estimates presented may be in error by as much as ±30 percent.

It will be noted that no mention has been made of radiological or blast injuries. As to the former, the information given by Oughterson and Warren[4] is succinct, and the casualty accrual, as well as mortality, can be independently computed if desired. As to the latter, extraordinarily little evidence is adduced in the available literature There has recently come to light additional information[5] which may be valuable in the re-estimation of the importance of this parameter in the Japanese detonations.

It is likely that the mortality in areas close to ground zero is a complex function of the interaction of three physical forces upon the victims in relation to their particular environments; thermal radiation, blast and shock, and ionizing radiation. Skin burns compose only a fraction of the total casualty picture. This paper considers only the thermal problem, whereas in a complete casualty prediction study for logistic planning, it must be combined with the other casualty-producing factors in order to give a thorough picture of the over-all medical burden.

In another communication in which the author estimated the relative contribution of skin burns to the total mortality picture of Nagasaki, the avoidance of skin burns, in certain areas, reduced the expected mortality from all 3 modalities by some 50 percent or more.

Attempts to extrapolate estimates of this character back to the time of the explosion, in order to estimate the medical burden immediately after the attack, are subject to several uncertainties. It is known that many seriously burned persons, who survived immediately, died within 24 hours; many more died in the first week. The percentage of persons who had significant burns but survived past only the first few hours is not known. On the basis of statements of Japanese doctors, however, it is probable that this figure was in the neighborhood of 65%, including persons with first degree burns. It appears likely that about one-half of these were "burn casualties," that is, they were incapacitated primarily by reason of their burns Using this estimate and interpolating along a semi-logarithmic scale (Figure 4), to 6.3% at 20 days, it is shown that in the first week some 45 percent of seriously burned survivors died; of those who lived one week with severe burns, about 40 percent died in the ensuing week; 35 percent died in the following week The death rate for persons with serious burns after this point was sharply reduced, although there continued to be deaths for months afterward The assumption of a weekly mortality rate of 45-30 percent of those significantly burned is seen to be consistent with the observation of Japanese doctors right after the explosion, with Oughterson's observation at 20 days, and with clinical experience in other situations.

If the estimate herein of 8355 persons at 20 days with significant burns, is correct, there were some 30,600 persons alive with significant burns immediately after the detonation, of whom 22,245 died in the first 3 weeks.

There will be no further work in the analysis of burn data from Nagasaki as such. The results of the foregoing work will be employed as a check point for the work in evaluating the burn hazard under DASA NWER Subtask 03.062.

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2. Oughterson, A.W., et al, Statistical Analysis of the Medical Effects of the Atomic Bombs, U.S. Atomic Energy Commission TID-5252, February 1955.

3. Auxier, J., personal communication, Dec. 1963.

4. Oughterson, A.W., Warren, S., Medical Effects of the Atomic Bomb in Japan, Nat. Nuclear Energy Series VIII, McGraw-Hill, N.Y. 1956.

5. Deal, J., personal communication, May 1964.

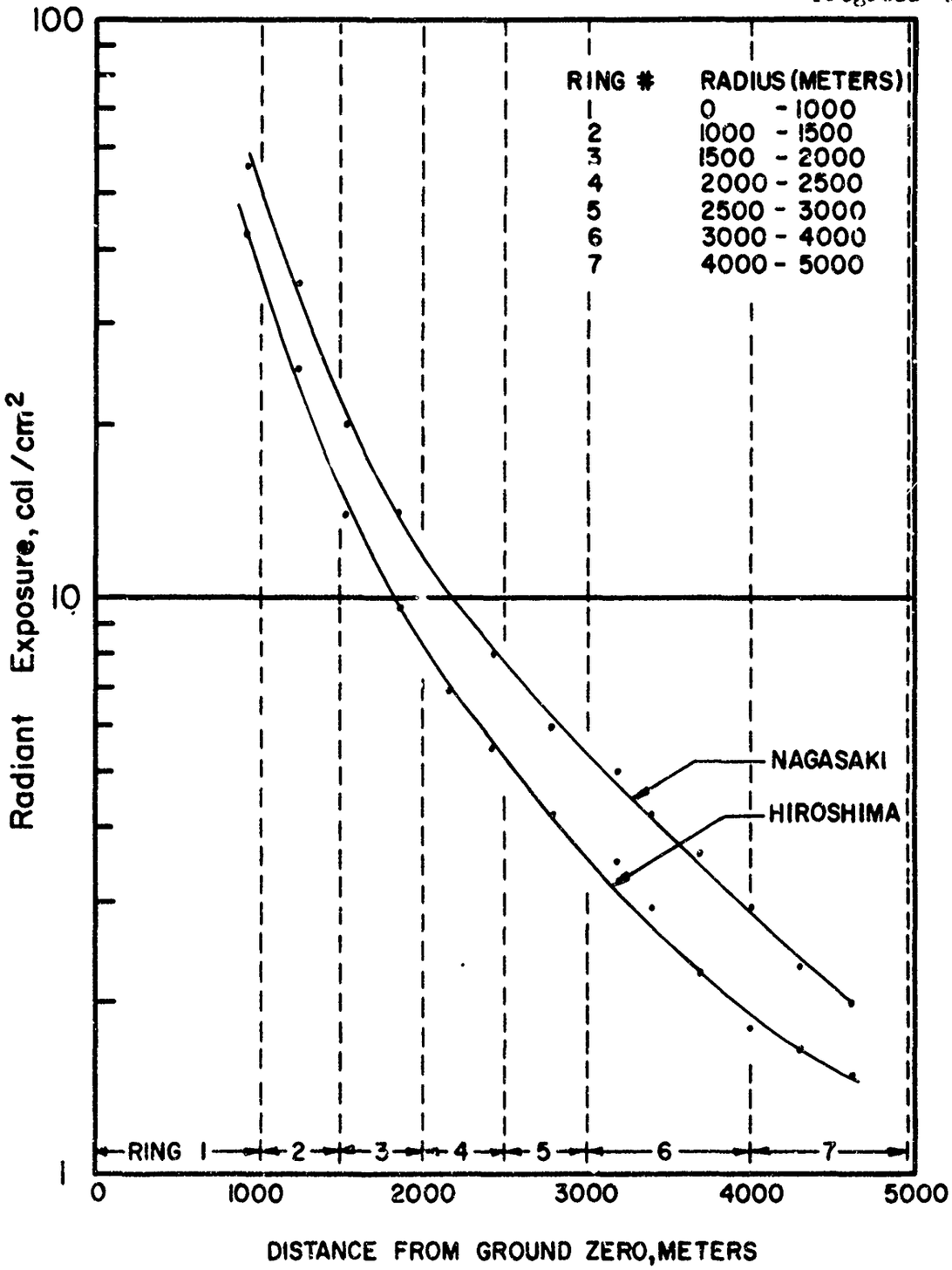

FIGURE 1. RADIANT EXPOSURE AS A FUNCTION OF DISTANCE FROM GROUND ZERO AT NAGASAKI AND HIROSHIMA

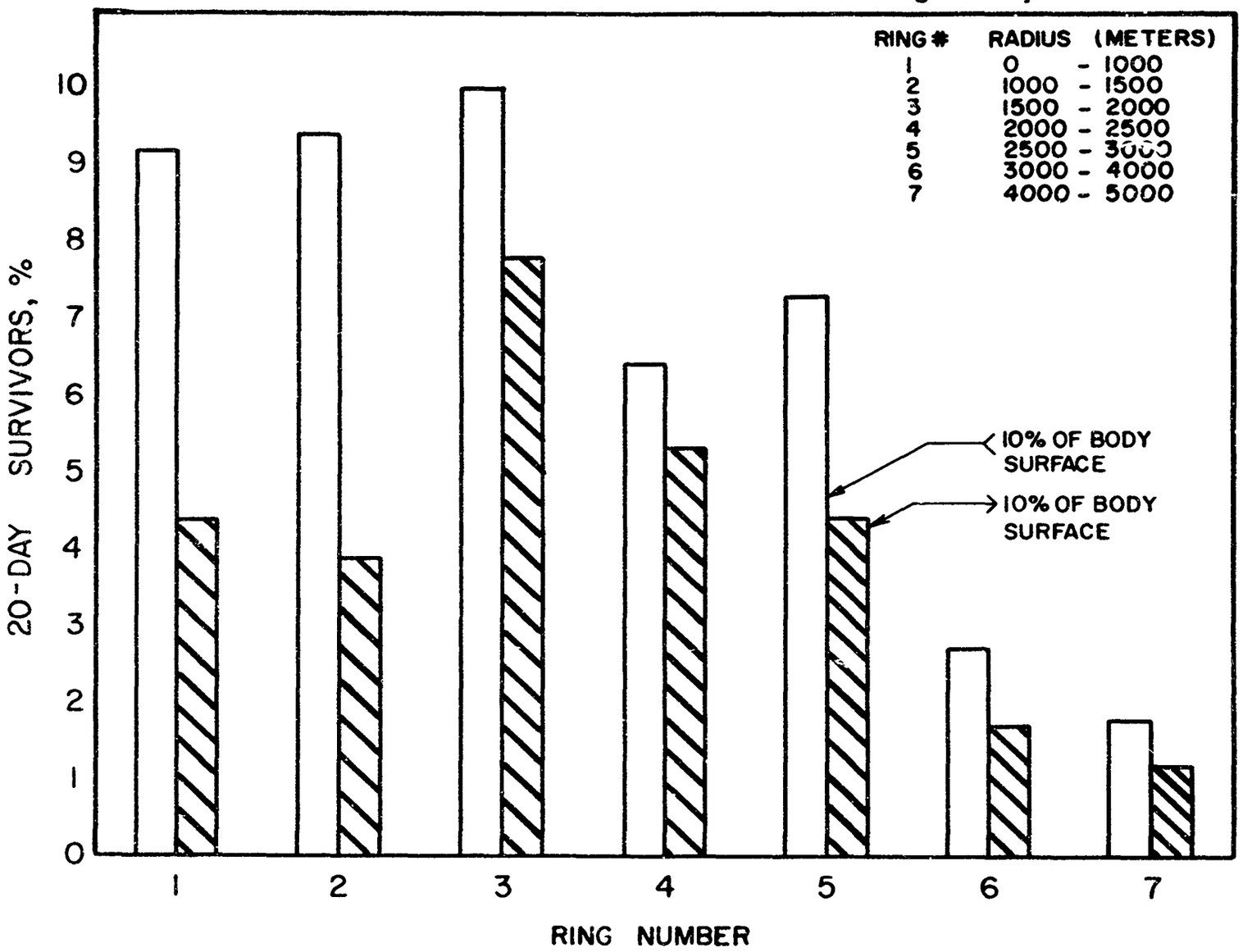

FIGURE 2. PERCENT OF 20-DAY SURVIVORS AT NAGASAKI WITH 2nd OR 3rd DEGREE BURNS ON 10 PERCENT OR LESS OF THE BODY SURFACE AND MORE THAN 10 PERCENT OF THE BODY SURFACE AS A FUNCTION OF DISTANCE FROM GROUND ZERO

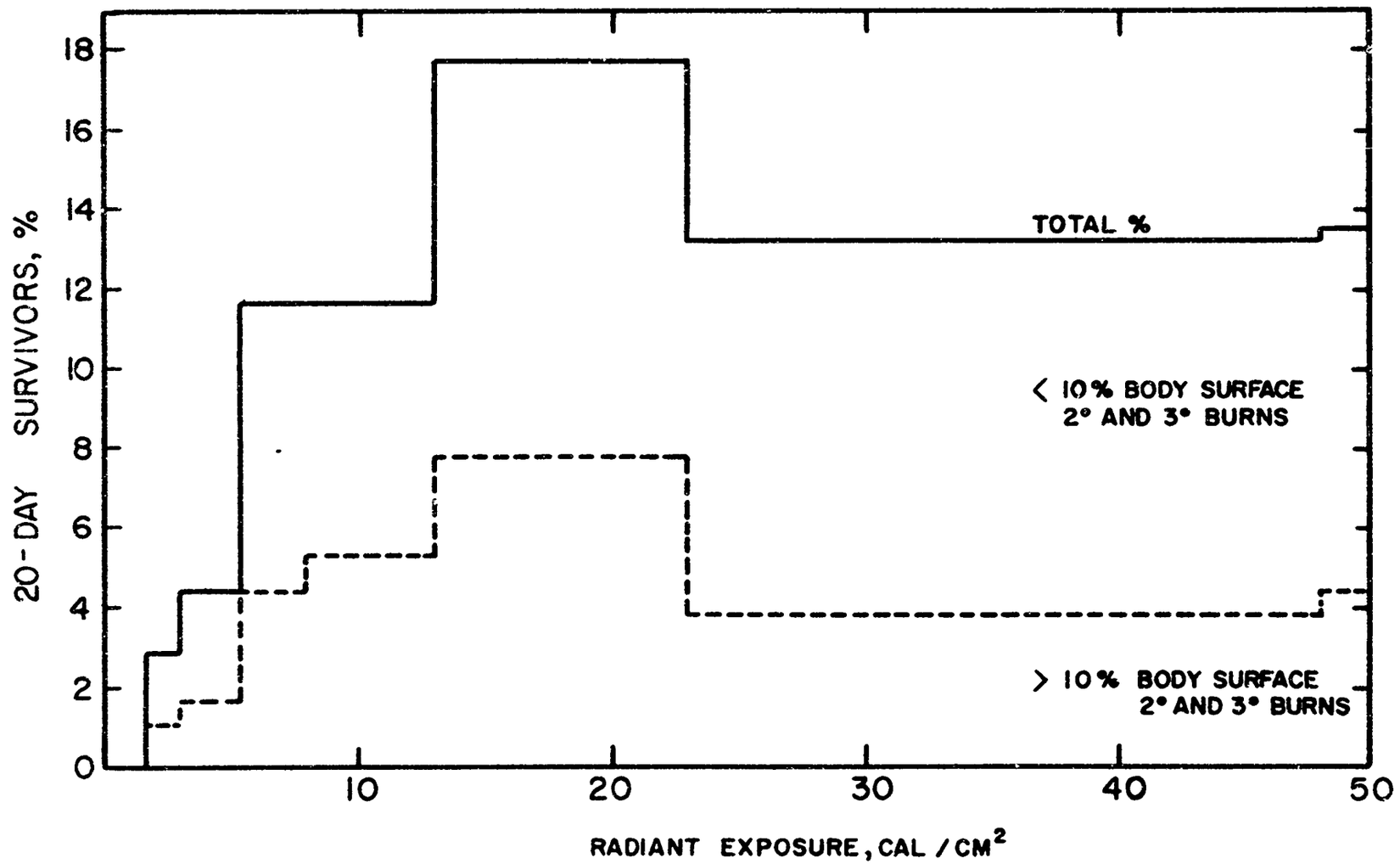

FIGURE 3. PERCENT OF 20-DAY SURVIVORS AT NAGASAKI WITH 2nd AND 3rd DEGREE BURNS ON 10 PERCENT OR LESS OF THE BODY SURFACE AND MORE THAN 10 PERCENT OF THE BODY SURFACE AS A FUNCTION OF THERMAL LOAD

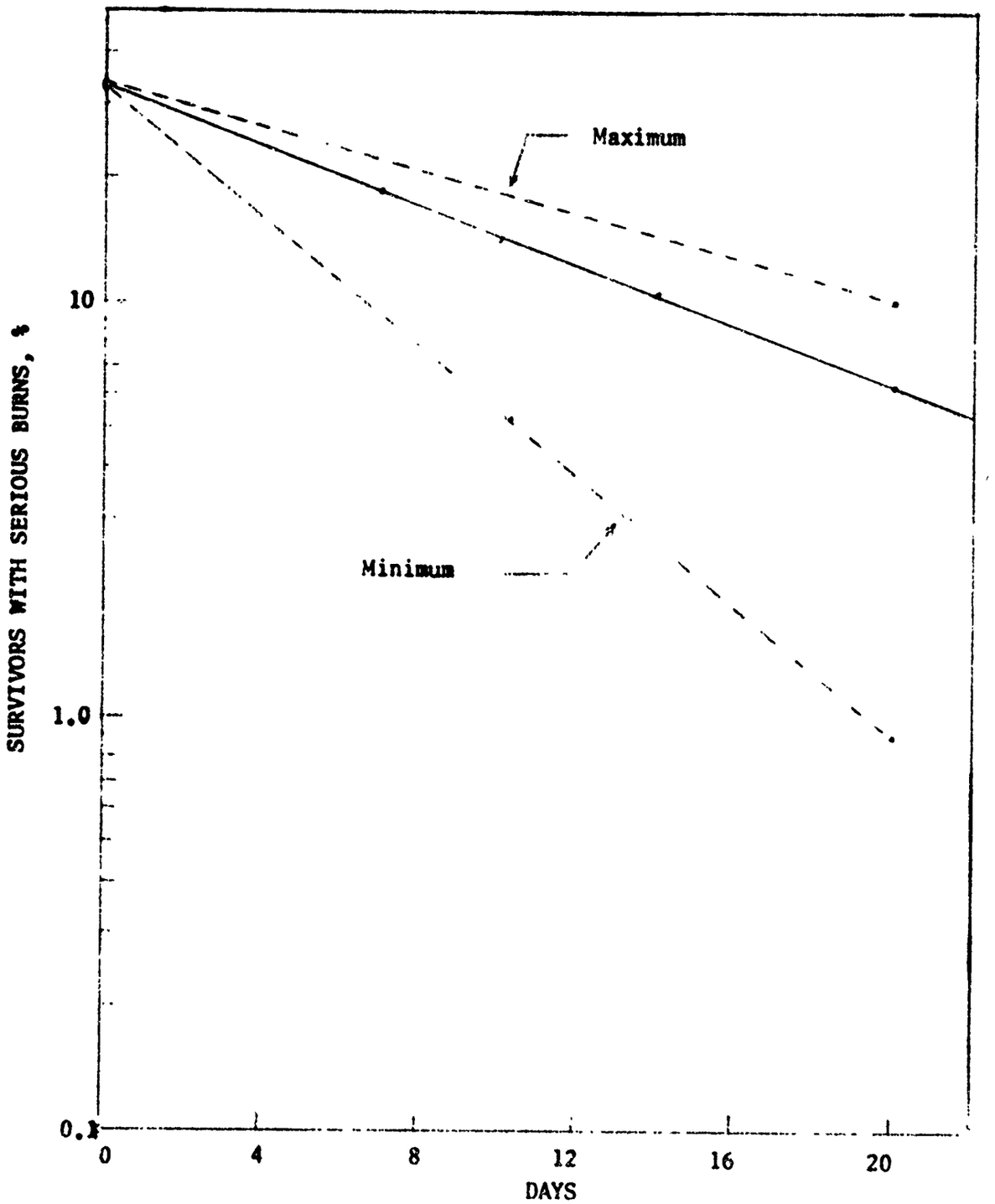

FIGURE 4 PERCENT OF THOSE SURVIVING AT NAGASAKI WHO HAD SERIOUS BURNS

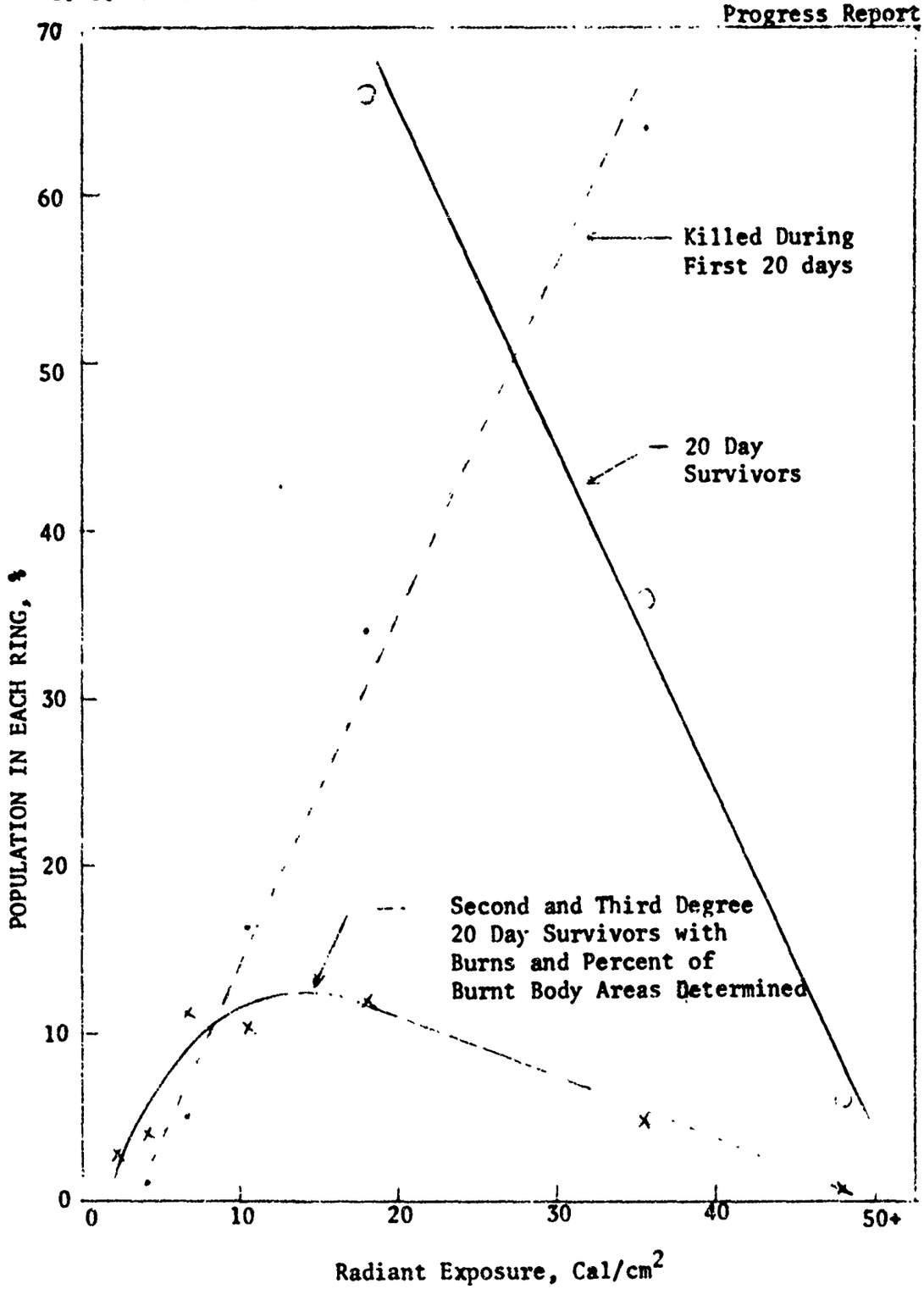

FIGURE 5 PERCENT OF POPULATION IN EACH RING SURVIVING AT 20 DAYS AND PERCENT OF 2ND AND 3RD DEGREE, BURNED 20 DAY SURVIVORS WITH DETERMINED BODY BURNS AS A FUNCTION OF RADIANT EXPOSURES.

TABLE 1

RADIANT EXPOSURES AT VARIOUS DISTANCES FROM GROUND ZERO, NAGASAKI AND HIROSHIMA

Distance from Ground Zero			Slant Range (Miles)	Nagasaki Radiant Exposure (Cal/cm^2)	Hiroshima		
Meters ($X10^3$)	Feet ($X10^3$)	Miles			Radiant Exposure(1) (Cal/cm^2)	Atmospheric Attenuation Factor	Corrected Radiant Exposure (Cal/cm^2)
0.925	3	0.57	0.66	56	47	0.90	42.3
1.23	4	0.76	0.83	35	28	0.89	24.9
1.54	5	0.95	1.01	20	16	0.875	14
1.85	6	1.14	1.19	14	11	0.865	9.5
2.16	7	1.33	1.37	10	8	0.854	6.9
2.43	8	1.51	1.55	8	6.5	0.846	5.5
2.78	9	1.70	1.74	6	5	0.838	4.2
3.18	10	1.90	1.92	5	4.2	0.833	3.5
3.40	11	2.09	2.12	4.2	3.5	0.828	2.9
3.70	12	2.28	2.30	3.6	2.7	0.824	2.25
4.0	13	2.47	2.49	2.9	2.2	0.822	1.8
4.32	14	2.65	2.68	2.3	2.0	0.821	1.65
4.63	15	2.84	2.87	2.0	1.8	0.820	1.48

(1) Not corrected for atmospheric attenuation

TABLE 2

THE PORTION OF THE BODY BURNED FOR VARIOUS RANGES OF RADIANT EXPOSURES AT NAGASAKI

Radiant Exposure (cal/cm^2)	Percent of 20-day survivors with burns (1)	Percent of 20 day survivors with 2nd degree burn as most severe (1)	Percent of Those living 20-days later with 2nd degree burn as most severe	Distribution of 20-Day Survivors with 2nd Degree Burn as Most Severe by Body Area Burnt (2)					
				Percent of Body Area Burnt					
				<2	2-9	10-19	20-29	30-39	>40
>48	22.7	75.4	17.2	25	26	14	8	3.6	1.8
48-23	24	71.6	17.2	24	28	14	4	2.7	0
23-13	34.7	69	24	15	23.5	16.7	7.5	4.1	1.4
13-8	23.1	68.3	15.8	13	24	19.5	3	7.5	1.5
8-5.4	20.3	75.4	15.3	14	33	13.3	10.5	1.9	1.9
5.4-2.9	7.5	76.7	5.75	19	27.5	16	8.7	4.3	0
2.9-1.7	7.5	50	3.75	(20)	(25)	(15)	(10)	(5)	(0)

(1) Data taken from Table 9N of reference (2)

(2) Data taken from Table 10N of reference (2).

(3) Bracketed figures are estimated

TABLE 3

THE PERCENT OF TOTAL SURVIVORS WHO HAD 2ND DEGREE BURNS AS MOST SEVERE OVER VARIOUS PORTIONS OF THE BODY SURFACE

Ring No.	Radiant Exposure (cal/cm^2)	Percent of Total Survivors Who Had 2nd Degree Burns as Most Severe Over Various Percentages of Body Surface					
		Percent of Body Area Burnt					
		<2	2-9	10-19	20-29	30-39	>40
1	>48	4.3	4.5	2.4	1.5	0.62	0.31
2	48-23	4.1	4.8	2.4	0.69	0.46	0
3	23-13	3.6	5.7	4.0	1.8	1.0	0.34
4	13-8	2.1	3.8	3.1	0.47	1.2	0.24
5	8-5.4	2.1	5.1	2.0	1.6	0.29	0.29
6	5.4-2.9	1.1	1.6	0.92	0.5	0.25	0
7	2.9-1.7	(0.75)	(0.94)	(0.56)	(0.38)	(0.19)	(0)

(1) Bracketed figures are estimated.

TABLE 4

THE PERCENT OF THOSE LIVING 20 DAYS LATER AT NAGASAKI WHO HAD 3rd DEGREE BURNS AS MOST SEVERE OVER VARIOUS PORTIONS OF THE BODY SURFACE

Radiant Exposure (cal/cm^2)	Percent of 20-day Survivors with Burns(1)	Percent of 20-day Survivors with 3rd Degree Burn as most severe(1)	Percent of Those Living 20 days later with 3rd degree Burn as Most Severe	Distribution of 20-Day Survivors with 3rd Degree Burn as Most Severe by Body Area Burnt(2) Percent of Body Area Burnt					
				<2	2-9	10-19	20-29	30-39	>40
>48	22.7	15.9	3.6	4.5	6.3	2.7	0	1.0	0
48-23	24	18.3	4.4	2.7	8.5	3.7	2.7	0.6	0
23-13	34.7	19.5	6.8	2.0	8.8	5.1	2.0	0.7	1.0
13-8	23.1	18.7	4.3	0	12.0	4.5	2.3	0	0
8-5.4	20.3	13.2	2.7	0	4.8	4.8	1.9	1.0	1.0
5.4-2.9	7.5	5.5	0.41	1.4	2.9	1.4	0	0	0
2.9-1.7	7.5	12.5	0.94	(3.0)	(6.0)	(2.0)	(1.0)	(0)	(0)

(1) Data taken from Table 9N of reference (2)

(2) Data taken from Table 10N of reference(2)

(3) Bracketed figures are estimated

TABLE 5

THE PERCENT OF TOTAL SURVIVORS WHO HAD 3RD DEGREE BURNS AS MOST SEVERE OVER VARIOUS PORTIONS OF THE BODY SURFACE

Ring No.	Radiant Exposure (cal/cm^2)	Percent of Total Survivors Who Had 3rd Degree Burns as Most Severe Over Various Percentages of Body Surface Percent of Body Area Burnt <2	2-9	10-19	20-29	30-39	>40
1	>48	0.16	0.23	0.10	-	0.04	-
2	48-23	0.12	0.37	0.16	0.12	0.03	-
3	23-13	0.13	0.60	0.35	0.13	0.05	0.07
4	13-8	-	0.52	0.19	0.10	-	-
5	8-5.4	-	0.13	0.13	0.05	0.03	0.02
6	5.4-2.9	0.006	0.012	0.006	-	-	-
7	2.9-1.7	(0.028)	(0.056)	(0.019)	(0.009)	-	-

(1) Bracketed figures are estimated

TABLE 6

ESTIMATED POPULATION DENSITIES FOR LAND AREAS AT VARIOUS DISTANCES FROM GROUND ZERO AT NAGASAKI

Ring No.	Distance from Ground Zero (Miles)	Radiant Exposure (cal/cm^2)	Area (mi^2)	Population Density Per Square Miles(1)	Estimated No. of Persons in Ring
1	0-0.6	>48	1.13	25,500	29,000
2	0.6-0.9	48-23	1.42	4,400	6,250
3	0.9-1.2	23-13	2.00	4,400	8,800
4	1.2-1.6	13-8	3.51	4,400	15,400
5	1.6-1.9	8-5.4	3.31	5,100	16,900
6	1.9-2.5	5.4-2.9	8.34	5,100	42,500
7	2.5-3.1	2.9-1.7	10.90	5,100	55,600
		Total	30.61		

(1) Estimated population densities from reference (1).

TABLE 7

PATIENT LOADS WITH 2ND AND 3RD DEGREE BURNS AS OF THE 20TH DAY POST-DETONATION (NAGASAKI) AT VARIOUS DISTANCES FROM GROUND ZERO

Ring No.	Killed		Survivors	Number of Survivors 20th Day Post Detonation with 2nd and 3rd Degree Burns	
				Burns of 10% or Less of Body Surface	Burns of Greater than 10% of Body Surface
1	27,200		1,800	166	78
2		4,000	2,250	211	87
3	9,500	3,000	5,800	600	450
4		2,500	12,900	862	711
5		800	16,100	1180	720
6	1,300	400	42,100	1046	647
7		100	55,500	965	632
TOTAL			136,450	5030	3325
			Percent of survivors	3.8	2.5
			Percentage of survivors with significant burns=		6.3

TABLE 8

PERCENT OF TOTAL 20-DAY SURVIVORS (NAGASAKI) WITH 2ND OR 3RD DEGREE BURNS OF 10% OF THE BODY SURFACE OR LESS AND GREATER THAN 10% OF THE BODY SURFACE AS A FUNCTION OF RADIANT EXPOSURE

Radiant Exposure (cal/cm^2)	10% of Body Surface or Less	Greater than 10% of Body Surface
>48	9.23	4.35
48-23	9.39	3.86
23-13	10.3	7.74
13-8	6.42	5.30
8-5.4	7.33	4.47
5.4-2.9	2.72	1.68
2.9-1.7	1.77	1.16

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	Department of Defense Defense Atomic Support Agency Washington D.C., 20301

13. ABSTRACT The medical burden at Nagasaki i.e. the number of persons who required medical care as a result of receiving skin burns caused by thermal radiation, was determined as a function of the distance from ground zero and radiant exposure. The casualties were computed on the basis of available burn casualty and survival data and a re-estimate of burst conditions. Of an initial population of approximately 174,400,8355 persons, or 4.9% of the total population survived 20 days after the detonation after receiving serious burns. Of the 20-day survivors, 1800 had been been closer than 1000 meters to ground zero, 13.5% of whom had skin burns. A total of 5800 20-day survivors had been at distances of from 1500 to 2000 meters 18.1% of whom had skin burns. Of the 54,600 survivors who had been at distances of from 4000 to 5000 meters, only 2.9% had skin burns.

The data are presented in a form to allow estimates of casualties for situations resembling those at Nagasaki.

From an analysis of the casualty data and from estimates made by Japanese doctors of the number of persons who survived immediately after the detonation, a casualty rate curve has been derived for the 20-day interval following the detonation.

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SKIN BURNS GROUND ZERO THERMAL RADIATION RADIANT EXPOSURE BURN CASUALTIES SURVIVORS NAGASAKI						

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